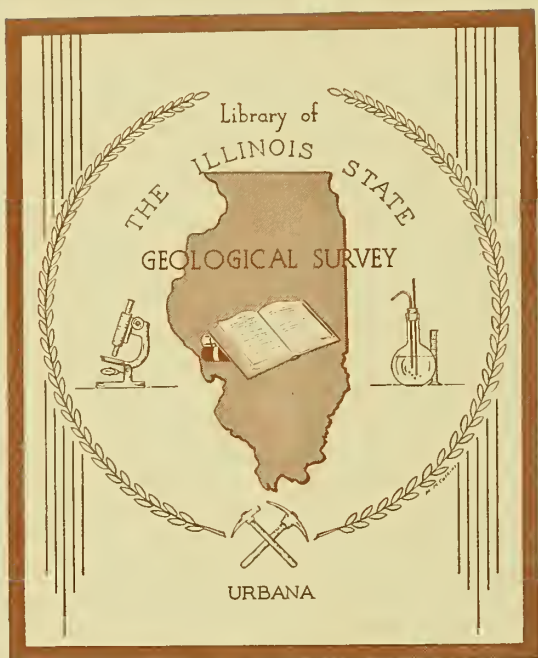




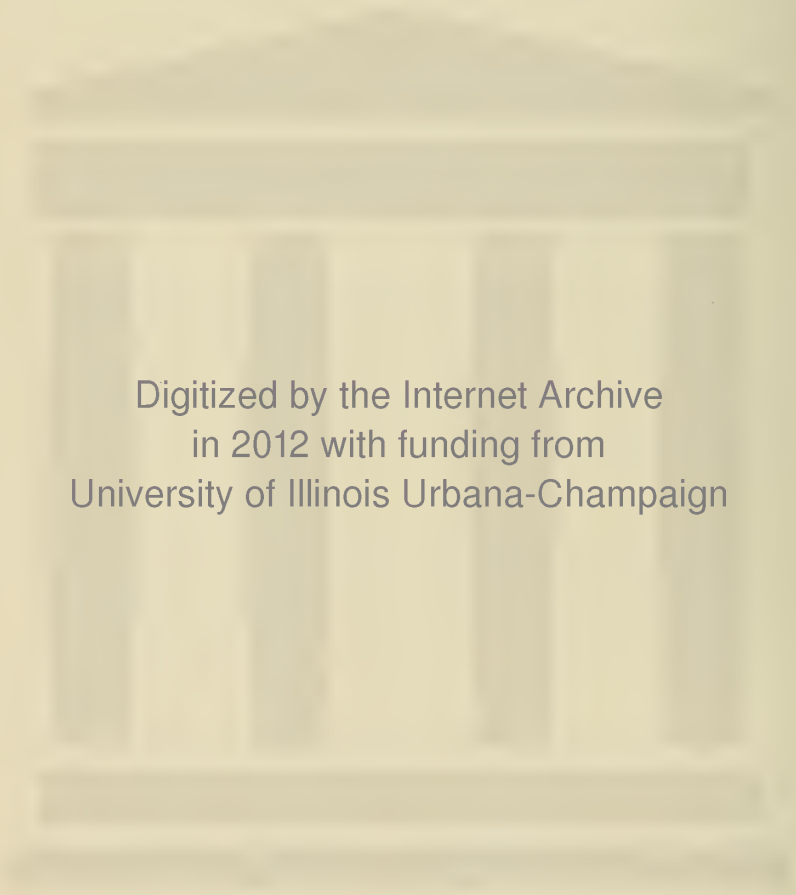
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REPORT OF INVESTIGATIONS—NO. 27

ANNA "KAOLIN" AS A NEW DECOLORIZING
AGENT FOR EDIBLE OILS

BY
R. J. PIERSOL, J. E. LAMAR and W. H. VOSKUIL



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ANNA KAOLIN AS A NEW DECOLORIZING AGENT FOR EDIBLE OILS

By R. J. Piersol, J. E. Lamar, and W. H. Voskuil

CHAPTER I—INTRODUCTION

By R. J. Piersol

SUMMARY

Source and market.—Previous to this study, no earths suitable for decolorizing edible oils were known to occur in Illinois, although for several years fuller's earth from Olmstead, Illinois, has been used extensively for bleaching mineral oils. The meat packing industry, cottonseed oil refineries, and the soap industry in the State, which have produced more than one-fourth of the United State's total of edible animal and vegetable oils, have imported fuller's earth in amounts estimated at 50 tons per day and at a delivered price of \$26.00 per ton for English earth and \$54.00 per ton for acid-treated earth from the Pacific coast.

The current study has revealed that the kaolin in the Mountain Glen area near Anna, Illinois, possesses bleaching qualities equal to those of the English XL fuller's earth, and it is estimated that this kaolin can be produced, processed, and marketed at a price competitive with that of the imported earths.

Scope of investigation.—The bleaching properties of representative Illinois clays have been studied systematically in an attempt to discover an earth suitable for bleaching edible oils. The research included laboratory experimentation on (1) the degree of decolorization effected by the earth, (2) the rate of filtration of oil through the earth, (3) the percentage of oil retained by earth, and (4) the active oxygen content of the bleached oil. More than 400 tests were made on 25 earths from localities within the State and on 21 from localities outside the State.

Results.—The investigation has resulted in the unexpected discovery that Anna kaolin possesses bleaching properties equal to those of the English XL fuller's earth, which is commonly accepted as a standard of comparison for bleaching tests made on vegetable and animal oils, and has the added unique advantage that it may be reprocessed many times without noticeable loss of bleaching strength, whereas other earths used to bleach edible oils are discarded after being used once. This may be partly due to the fact that as Anna kaolin

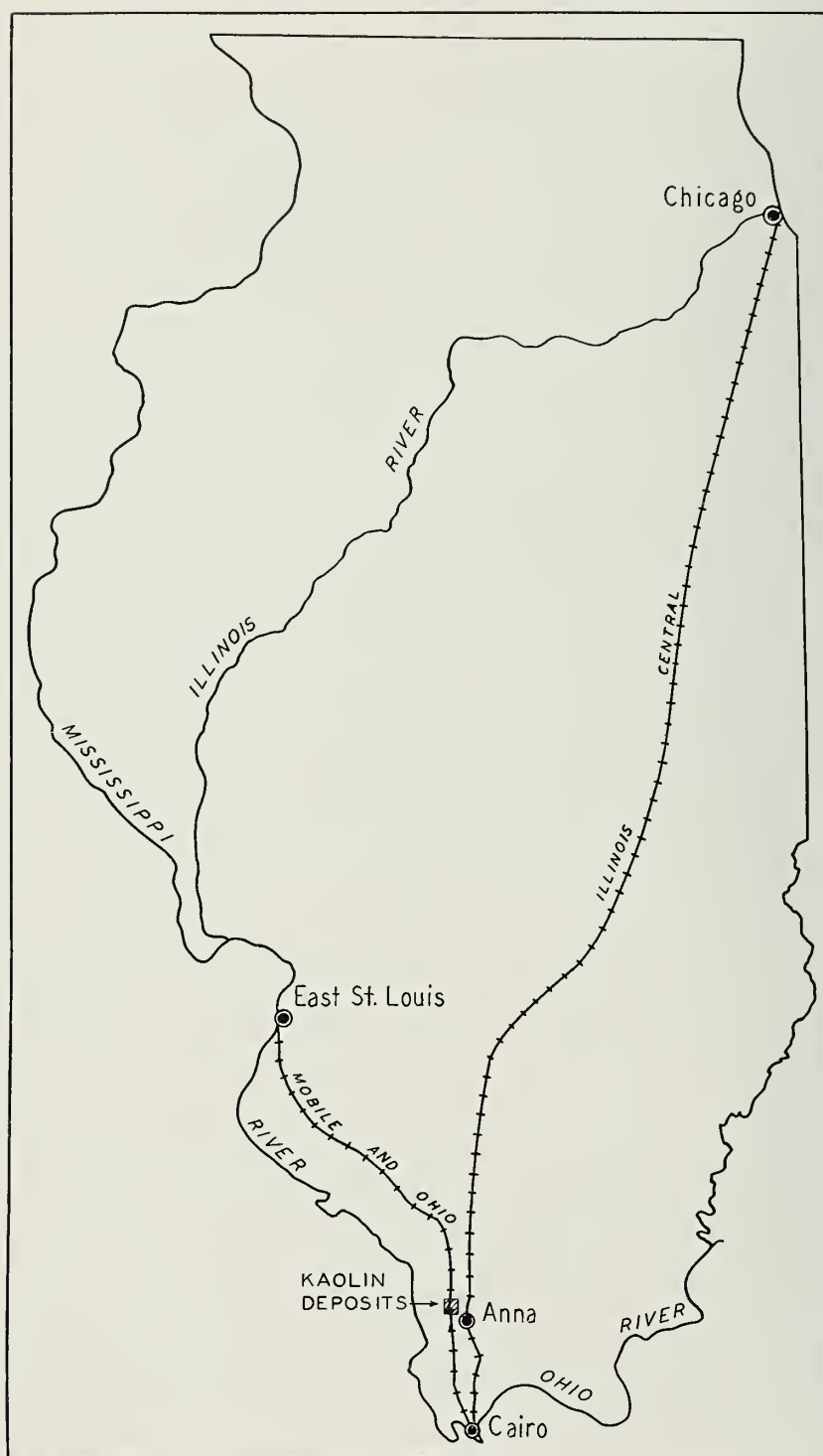


FIG. 1.—Map of Illinois showing the location of the Anna kaolin deposits.

is highly refractory it may be processed at a temperature of 600°C. as compared to 300° for other bleaching earths. It also has a critical temperature of dehydration as compared to a gradual dehydration for fuller's earth. Oil bleached by reprocessed Anna kaolin has a remarkably low active oxygen content averaging 0.0086 mols per 1000 grams as compared to an average experimental value of 0.0178 for oil bleached with English XL earth. An oxygen content in excess of 0.04 mols per 1000 grams causes a condition favorable to rancidity.

Resources and availability.—The deposits of Anna kaolin are located at Kaolin Station near Mountain Glen, Union County, Illinois (Fig. 1). Direct transportation is furnished by a spur of the Mobile and Ohio Railroad. During the World War the maximum production was 400 tons per day and a total of 278,000 tons was shipped. It is estimated that an additional 50,000 tons were produced before and after the war.

The reserve is large. Recently the Illinois Kaolin Company has proved an unworked deposit of uniform clay 200 by 200 feet, 40 feet thick, and overlain by 15 feet of overburden (Fig. 2, No. 3). This is equivalent to approximately 120,000 tons.

These deposits may be mined economically either by shaft or by steam shovel, depending on the desired rate of production.

Interpretation.—The following hypothesis has been developed in an attempt to explain research results. Apparently a clay, such as Anna kaolin, in the process of weathering passes through certain transitional zones when it may possess bleaching properties that are lost at certain stages of increased chemical and physical stability. It is not known why Anna kaolin should happen to be in this transitional zone whereas the true kaolins lack bleaching power. No relationship is evidenced between the chemical or mineral composition of earths and their bleaching activity, and the fact that the bleaching activity is not influenced by explosion or compaction indicates that it is not due to the texture of the earth.

INTRODUCTION

PURPOSE OF INVESTIGATION

The only bleaching earth which has been thus far developed within Illinois is the deposit of fuller's earth located near Ohmstead in Pulaski County,¹ but this earth is used only for bleaching mineral oils because edible oils treated with it become rancid.

¹Lamar, J. E., Preliminary report on the fuller's earth deposits of Pulaski County: Illinois State Geological Survey Report of Investigations No. 15.

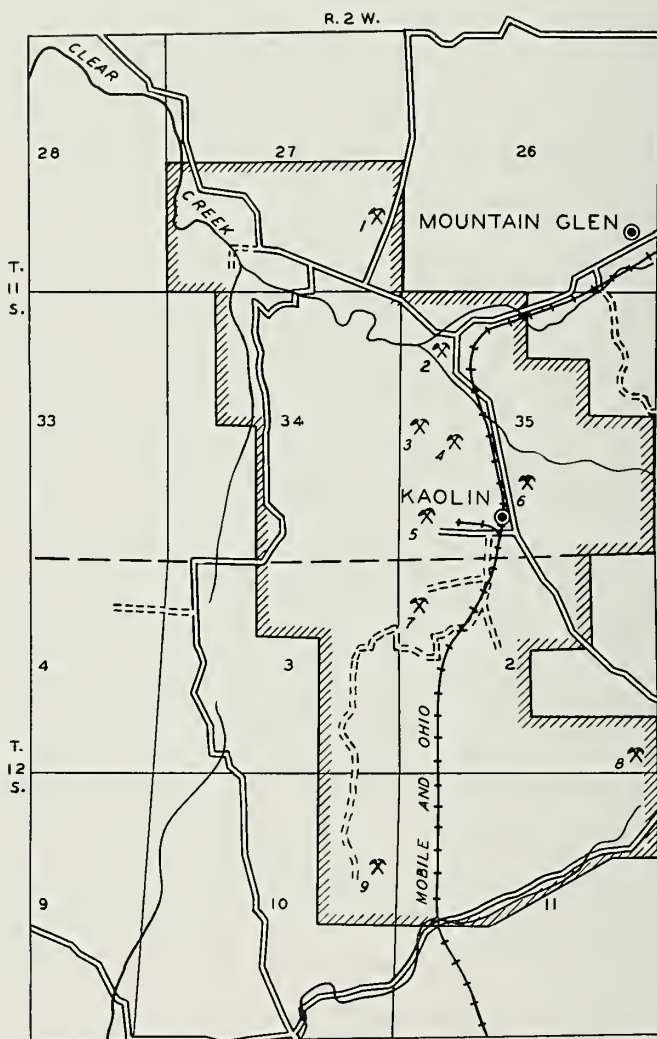


FIG. 2.—Map of the Mountain Glen region showing area known to include kaolin deposits of proved or probable commercial value. (After Parmelee and Schroyer, *Further investigation of Illinois fireclays*, Illinois State Geol. Survey Bull. 38D, p. 50, 1921.)

INDEX TO MINES AND PITS—1. Frederick E. Bausch (Mine No. 3). 2. French Clay Blending Company. 3. Illinois Kaolin Company (Mine F). 4. Frederick E. Bausch (Mine No. 2). 5. Illinois Kaolin Company (Pit K3). 6. Frederick E. Bausch (Mine No. 1). 7. Dr. Goodman. 8. Elmer Gant. 9. Maddox and Nixon.



FIG. 3.—View of the southwest wall of the “K” pit of the Illinois Kaolin Company.



FIG. 4.—Pit of Illinois Kaolin Company.

It seemed possible that other Illinois clays, radically dissimilar to fuller's earth, might also be found to possess bleaching properties. Therefore a systematic investigation of various clays other than fuller's earth within the State, was undertaken in an attempt to discover if any of them is suitable for bleaching edible oils. Sun-dried bleaching earth adheres strongly to the human tongue. Clays which, by this crude test, showed promise of bleaching strength were compared quantitatively to standard English NL fuller's earth as to (a) degree of decolorization, (b) rate of filtration, and (c) retention of oil in the filter cake.

Result of investigation.—This study resulted in the discovery that Anna kaolin warrants industrial utilization as a bleaching earth for edible oils and also mineral oils.

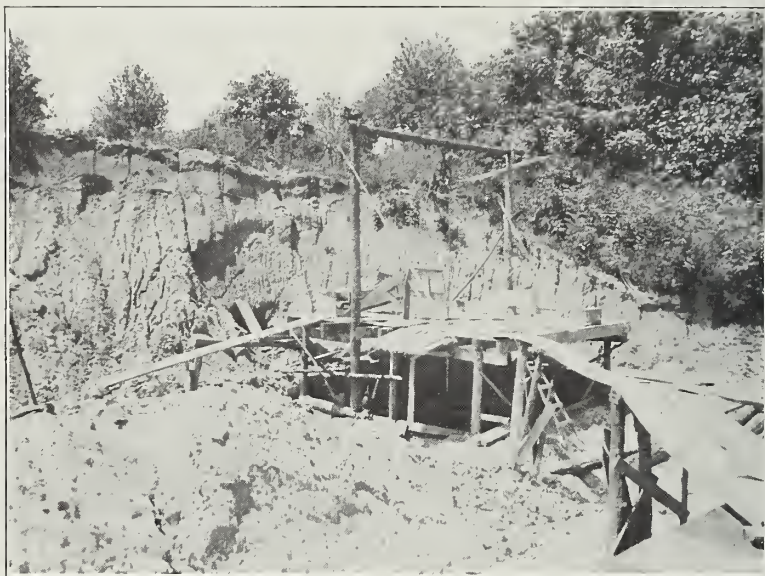


FIG. 5.—View of Dr. Goodman's mine in the NW. $\frac{1}{4}$ sec. 2, T. 12 S., R. 2 W.

Location of Anna kaolin deposits.—Anna kaolin derived its name from the fact that as early as 1865 a pottery was located at Anna, Illinois, which used the kaolin-like clay from the nearby deposits located in the vicinity of the present Kaolin Station in the Mountain Glen area.

The location of the Anna kaolin deposits is shown in figure 2. The area known to include deposits having proved or probable commercial value is delimited by the cross-hatched boundary. A spur of the Mobile and Ohio Railroad extends to pit K (Fig. 3) of the Illinois Kaolin Company. In 1916 kaolin was mined in this pit by steam shovel (Fig. 4). The other typical method of mining kaolin is by shaft as at the Goodman pit (Fig. 5).

EARTHS SUITABLE FOR OIL BLEACHING

The bleaching property of a substance is herein defined as its ability to remove color from a liquid. This may be accomplished (1) by the physical removal of colored particles by preferential adhesion, or (2) by a chemical change whereby a colored molecule becomes a colorless molecule. A bleaching agent may be an adsorptive substance such as fuller's earth, or a chemical such as chlorine which oxidizes or sulphur dioxide which reduces. Some products, as for instance cottonseed oil, may be decolorized by photo-chemical oxidation when exposed to sunlight.

The name fuller's earth was derived from the fact that it was found that a particular type of clay could be used for fulling woolen cloth. In the present article the term, fuller's earth, is limited to a specific bleaching earth such as the Olmstead earth, in which the clay mineral is montmorillonite. Kerr¹ shows smectite to be identical with montmorillonite. The French name for fuller's earth is "argile smectique" or smectite clay. The term montmorillonite is derived from the name of the town Montmorillon, France, which is the type locality of the mineral. Mineral analysis shows that all the fuller's earths herein studied are montmorillonite clays.

The characterization of an earth as a bleaching earth is only relative because all earths have some capacity for bleaching. The efficiency of various bleaching reagents, measured by the amounts of benzol clarified, is as follows:²

<i>Kind of earth (one gram)</i>	<i>Amount of benzol clarified (cc.)</i>
Fuller's earth	30
Bauxite	30
Bone charcoal	14
Iron oxide	10
Kieselguhr	2
Kaolin	2

According to this, earths such as kieselguhr or kaolin may be considered inactive as compared to fuller's earth. The bleaching strength of some earths may be increased several fold by treating them with acid or by processing which consists of heating it to a temperature high enough to drive off a large proportion of the water of hydration.

Fuller's earth used for bleaching mineral oils may be reused—that is the oil retained in the filter cake may be dissolved out and the earth reprocessed—from three to eight times, depending on the particular earth and the particular oil, but with each reprocessing the bleaching strength of the earth decreases. Natural refractory earth may be reprocessed more readily than an earth which metamorphoses at low temperatures. Silica gel, which is one of several synthetic substances that possess strong bleaching properties, may be reprocessed indefinitely without loss of bleaching strength because it is ex-

¹ Kerr, P. F., *American Mineralogist*, vol. 17, 1932, p. 192.

² Dunstan, *Zeitschrift für Chemie und Industrie der Kolloide*, p. 124, 1923.

tremely refractory. It has not been found feasible to reprocess earths used for bleaching edible oils.

Any earth used for bleaching edible oils must not only be capable of decolorizing the oil but must neither impart a clayey taste and odor nor oxidize the oil to such a degree that an unsaturated rancid fatty acid forms.

In Illinois, the fuller's earth from Olmstead and earths from without the State have been used for bleaching lubricating oils. English XL fuller's earth has been used most extensively for bleaching edible oils but at present acid-treated earth from California is gaining favor, despite its greater cost, because smaller amounts of it are required.

The results of careful laboratory experimentation indicate the relative bleaching ability of various earths. However, it is known that a smaller amount of earth may be required in actual commercial operation than is indicated by small scale tests. No bleaching earth should be adopted for industrial purposes until it has been tested on a commercial scale.

A detailed review of the various theories of bleaching and descriptions of commercial bleaching installations may be obtained from the articles listed in the appended bibliography.

CHAPTER II—TESTING METHODS AND RESULTS

By R. J. Piersol

GENERAL

The comparative bleaching strengths of various earths have been obtained by mixing a given amount of each earth with a given amount of cottonseed oil, treating the mixture at a given temperature and for a given time and observing the comparative color of the bleached oil. The rate of filtration, the amount of oil retained, and the peroxide oxygen content were also determined. The determination of the peroxide oxygen content is important in that the peroxides break down to form rancid fatty acids.

In additional tests the effects of (1) different proportions of earth to oil, (2) different times and temperatures of processing, (3) differences in texture of the earth, and (4) reprocessing of the earths were noted. Other tests were made with motor and engine oils. The results of these tests are given in Tables 1-7.

METHODS OF EXPERIMENTATION¹

The procedure adopted for the laboratory experiments on cottonseed oil in this study is as follows: The earths to be tested were dried at 110°C. to expel excess moisture and then pulverized to pass a 200-mesh screen. Three hundred grams of oil were placed in a beaker and heated to the specified temperature by a Bunsen burner. Measured amounts of the earth were added and the mixture was stirred with 1/2-inch paddles motor driven at 250 ± 10 R. P. M. for five minutes in a digester (Fig. 6). The entire mixture was then poured into a 150 mm. Buechner funnel and filtered through one thickness of Whatman's filter paper No. 1. The filter paper was wet with oil and vacuum was applied before the digested sample was poured onto the filter because if dry paper is used unfiltered oil passes beneath the edge of the paper, and if the paper is wet with water the bleached oil is clouded with the resultant water emulsion. The vacuum, which was produced by a water aspirator, was about 17 mm. mercury. After sufficient oil had passed through the filter to insure clearness, a sample was collected for color reading. The sample was cooled and the color immediately determined. However, as the tests were made in order to ascertain the comparative bleaching strengths of various earths,

¹The procedure for testing the ability of various earths to decolorize cottonseed oil has been standardized by the American Oil Chemists Society, last revision August 1, 1931; details may be obtained from the Secretary of the Society.

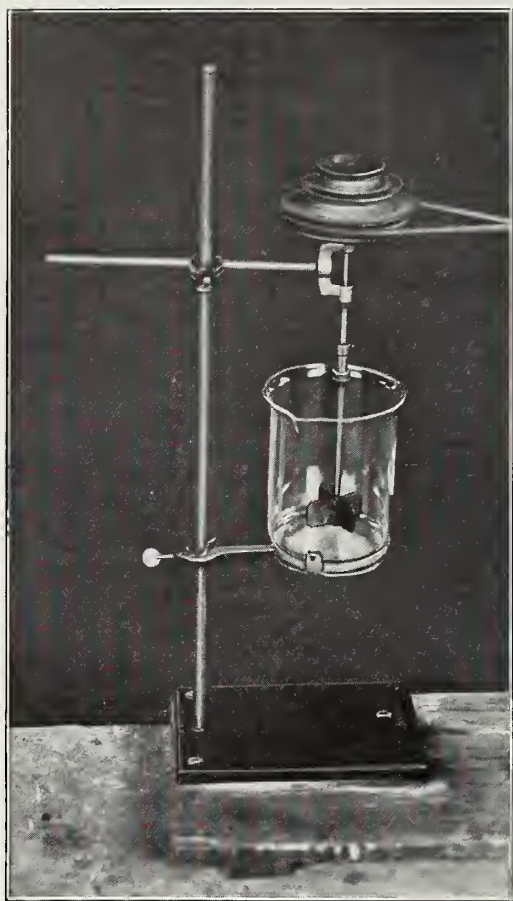


FIG. 6.—Beaker, fitted with motor-driven paddles, in which mixtures of oil and earth were digested.

rather than to bleach a particular oil to a prescribed color, instead of using the standard Lovibond color scale the color was compared to that given by the standard quantity of English XL earth.

It is essential to bleach certain cottonseed oil products as low as 15 to 20 yellow and 1 to 1.5 red in the Lovibond color scale; in others the color may run as high as 20 to 30 yellow and 2 to 3 red. It is customary to bleach lard as low as 5 to 10 yellow and 1 to 1.5 red.

In the tests on English XL earth, the mixture of oil and earth was digested at 120° C. for five minutes (Table 1); in the tests on Anna kaolin the earth was processed at 600° C. for one hour and the oil and earth was digested at 120° C. for five minutes (Table 2). In the tests on lubricating oils, 500 grams of oil and 75 grams (15 per cent) of bleaching earth were used and the mixture was digested at 82° C. for 25 minutes (Tables 6 and 7).

The determination of peroxide oxygen followed D. H. Wheeler's method.² Quoting Mr. Wheeler, the method is:

"Three to ten grams of oil are dissolved in 50 cc. of solvent mixture (60 per cent glacial acetic acid, 40 per cent chloroform) and 1 cc. of saturated potassium iodide solution added. The mixture is stirred by giving a rotary motion to the flask. After exactly one minute from the time of addition of the potassium iodide, 100 cc. of water are added and the liberated iodine is titrated with 0.1 N or 0.01 N sodium thiosulfate, depending on the amount of iodine liberated. Starch is added toward the last as indicator. Vigorous shaking is necessary at the very last to remove the last traces of iodine from the chloroform layer. The results may be conveniently expressed as mols of peroxide per 1000 gm. of oil, calculated according to the following formula:

$$\text{mols of peroxide,} \quad M = \frac{.5\text{cc.} \times N}{\text{gm}}$$

cc. = cc. of thiosulfate

N = normality of thiosulfate

gm. = grams of oil"

EXPRESSION OF RESULTS

The prime results of the tests concerned the comparative color of the bleached oils after being treated with the various earths according to different procedures. The standard color, against which the color of the bleached cottonseed oil was compared, was established by bleaching 300 grams of cottonseed oil with 18 grams of English XL fuller's earth, treated according to the standard procedure at a temperature of 120° C. for five minutes. This color is designated as "A". In all tests on bleaching cottonseed oil the color of the bleached oil is designated as "AA" if it excels the standard color, "A" if it equals the standard color, and "B", "C", or "D" according to how nearly it

² Wheeler, D. H., *Oil and Soap*, April, 1932, pp. 89-97.

approaches the standard color. Colors designated as "B" are satisfactory, those designated as "C" show some bleaching effects but are unsatisfactory, and those designated as "D" show little effect and consequently are also unsatisfactory.

In the tests on lubricating oils, the color obtained by using German terrana fuller's earth, treated according to the standard procedure in testing lubricating oils, was established as a standard and the same scheme of letters shows relative bleaching obtained by various earths.

The rate of filtration is expressed as the number of seconds required for 200 cc. of oil to filter.

The amount of the oil retained in the filter cake is expressed as percentage of the original weight of the earth.

The amount of peroxide oxygen in cottonseed oil, determined approximately seven weeks after the oil had been bleached, is expressed as the number of mols per 1000 grams. One-half of the sample had been stored in the dark and the other had been exposed to light. The peroxide oxygen content of unbleached cottonseed oil stored in a tin container is .0218 mols per 1000 grams, and in the same oil stored in glass exposed to diffused light for eight weeks it is only .0075 mols.

TESTS ON BLEACHING COTTONSEED OIL WITH ENGLISH XL FULLER'S EARTH

Several tests (Table 1) on bleaching cottonseed oil were made using different amounts of English XL fuller's earth. These amounts are also expressed in percentages which are the ratios of the weights of earth to the amount of oil (300 grams). The color of the bleached oil in these tests is directly related to the amount of earth used. With the amount of earth adopted for the standard color, the oil requires 50 seconds to filter and the oil retained in the filter cake is equal to 42 per cent of the weight of the earth. The rate of filtration for different amounts of earth does not vary regularly with variation in the amount but in general the proportion of oil retained increases with decreasing amounts of earth.

The oxygen content of the bleached oil was increased by heating as shown by the results of tests Nos. 30 and 31 (Table 1). In test 30 the oil was not heated but in test 31 it was heated for three hours at a temperature of 210° C. Data by Wheeler indicate that peroxide oxygen in excess of .04 mols is potentially capable of producing rancidity. Inasmuch as the oxygen content in the heated oil is .0357 mols, it is evident that heating has increased it to a point near the maximum permissible.

TABLE 1—Results of tests on bleaching 300 grams of cottonseed oil with English XL fuller's earth, digested at 120°C. for five minutes

Laboratory test number	Earth used		Color of bleached oil.	Rate of filtration		Retention of oil (per cent of original earth)		Peroxide oxygen mols per 1000 grams	
	Grams	Ratio to oil (per cent)		Number of seconds	Mean	Individual	Mean	Storage	
								Dark	Light
95.....	30	10.0				33			
73.....	22	7.3	AA	60		38		.0057	.0089
94.....	20	6.7				31			
72.....	20	6.7	AA	60		39		.0167	.0063
71.....	18	6.0	A	50	50	37	42	.0057	.0062
15.....	18	6.0	A	50		46			.0218
16.....	18	6.0	A	50		44			.0298
30.....	18	6.0							.0169
31.....	18	6.0						(a)	.0357
70.....	16	5.3	B	50		35			
69.....	14	4.7	C	40		43			
68.....	12	4.0	C	40	52.5	61	50		
78.....	12	4.0	C	65		52			
90.....	12	4.0				38			
77.....	10	3.3	C	60		42			
76.....	8	2.7	D	60		50	44	.0148	.0086
88.....	8	2.7				38			
93.....	7	2.3				41			
75.....	6	2.0	D	40		50	52.5	.0108	.0168
87.....	6	2.0				55			
92.....	5	1.7				54			

(a) Sample of cottonseed oil heated for 3 hours at a temperature of 210°C.

TESTS ON BLEACHING COTTONSEED OIL WITH ANNA KAOLIN

RESULTS OF USING DIFFERENT AMOUNTS OF EARTH

Tests on bleaching cottonseed oil with different amounts of Anna kaolin that had been processed at 600° C. for one hour were made (Table 2). From this table it may be seen that only 16 grams of kaolin were required to obtain the standard color, but that it required 88 seconds of time for filtration in comparison to the 50 seconds required for English XL earth. In general, the larger amounts of earth required longer time for filtration, as might be expected. However, the rate of filtration is not a serious factor in industrial use, as it may be controlled by filter press pressure. In bleaching lubricating oils, silica sand may be added to the earth to increase the rate of filtration.

It may be noted that the 16 grams of earth retains a lesser proportion (mean 49.3 per cent or 7.9 grams) of oil than either any greater or any smaller amounts of earth. The 18 grams of English XL earth, which gives the same color as 16 grams of Anna kaolin, retained 7.6 grams of oil, a difference of 0.3 grams or 0.1 per cent of the original 300 grams of oil. Consequently, if the oil retained in the filter cake could not be reclaimed, the use

of the Anna kaolin would involve 0.1 per cent greater loss of oil, but normally the retained oil is dissolved out, in which case the advantage again lies with the Anna kaolin in that the amount of earth from which retained oil is recovered is 11 per cent less.

It should be noted that the peroxide oxygen content of the bleached oils is very low.

TABLE 2—*Results of tests on bleaching 300 grams of cottonseed oil with Anna kaolin, digested at 120°C. for five minutes*
(Earth processed at 600°C. for one hour)

Laboratory test number	Earth used		Color of bleached oil	Rate of filtration		Retention of oil (per cent of original earth)		Peroxide oxygen mols per 1000 grams	
	Grams	Ratio to oil (per cent)		Number of seconds	Mean	Individual	Mean	Storage	
								Dark	Light
80.....	30	10.0	AA	200	.....	53	.....	.....	.....
83.....	22	7.3	AA	160	.....	60	.....	.....	.....
82.....	20	6.7	AA	110	.....	58	.....	.0043	.0018
81.....	18	6.0	AA	80	.....	62	.....	.0020	.0020
17.....	18	6.0	AA	120	96	61	62	.....	.0087
18.....	18	6.0	AA	120		64		.0012	
59.....	18	6.0	AA	65		58		.....	
36.....	17	5.7	AA	100	100	59	58.5	.....	.....
37.....	17	5.7	A	100		58		.....	
19.....	16	5.3	A	100		42		.....	
20.....	16	5.3	A	90	88	46	49.3	.....	.....
57.....	16	5.3	A	70		51		.....	
58.....	16	5.3	A	70		54		.....	
67.....	16	5.3	A	130	75	44	61	.....	.....
80.....	16	5.3	A	70		59		.0126	.0021
38.....	15	5.0	A	70		61		.....	
39.....	15	5.0	B	80	76	61	59	.....	.....
21.....	14	4.7	B	100		56		.....	
22.....	14	4.7	B	85		71		.0009	
55.....	14	4.7	B	70	60	56	59	.....	.....
56.....	14	4.7	B	65		54		.....	
79.....	14	4.7	B	60		62		.0019	.0040
101.....	14	4.7	.....	.....	.....	54	.....	.....	.....
74.....	12	4.0	C	60	.....	67	.....	.....	.....
100.....	10	3.3	.....	.....	.....	58	.....	.....	.....
99.....	8	2.6	.....	.....	.....	58	.....	.....	.....
85.....	6	2.0	D	60	.....	83	75	.....	.....
98.....	6	2.0	.....	.....	.....	67		.....	
97.....	4	1.7	.....	.....	.....	95		.....	

RESULTS OF DIFFERENCES IN TIME AND TEMPERATURE OF PROCESSING

Bleaching earths are ordinarily processed or activated by heating at a specified temperature for a definite period of time. Tests were made on Anna kaolin to determine the influence of different temperatures and different periods of processing (Table 3). It may be noted that the bleaching power is

reduced by heating to temperatures above 600° C. At temperatures between 600° and 700° the earth changes from grayish white to light cream color, suggesting a metamorphosis which apparently affects its bleaching strength. The rate of filtration increases with increase in processing temperature so that for earth heated to 800° it is twice as rapid as for earth heated to 600° C. It is interesting to note that the Anna kaolin possesses its full bleaching power without being processed and in this respect is unique among bleaching earths. The amount of oil retained by the filter cake decreases generally with increase in temperature or increase in time of processing. The peroxide oxygen content is apparently unaffected except that in the unprocessed earth it is very close to the maximum permissible.

TABLE 3—Results of bleaching 300 grams of cottonseed oil with 16 grams of Anna kaolin, digested at 120°C. for five minutes

(Earth processed at different temperatures and for different periods)

Laboratory test number	Earth processed		Color of bleached oil	Results of bleaching				
	Temperature Degrees C	Number of hours		Rate of filtration		Retention of oil (per cent of original earth)		Peroxide oxygen content, mols per 1000 grams
				Number of seconds	Mean	Individual	Mean	
45.....	1000	1	C	40	50	40	41	.0113
48.....	1000	1	C	60		42		.....
43.....	800	1	B	40		46		.0177
44.....	800	1	B	40	40	48	47	.0105
25.....	700	2	B	80		41		.....
26.....	700	2	B	75		43		.....
27.....	700	2	B	80	78	45	43	.0109
32.....	700	1	B	120		45		.....
33.....	700	1	B	75		93	57	54.3
34.....	700	1	B	85	61		.0013	
19.....	600	1	A	100	42		.....	
20.....	600	1	A	90	88	46	49.7	.....
57.....	600	1	A	70		51		.....
58.....	600	1	A	70		54		.....
67.....	600	1	A	130	93	44	61	.0021
80.....	600	1	A	70		59		.....
35.....	500	1	A	90		62		.....
46.....	500	1	A	90	105	61	64	.0145
47.....	500	1	A	100		61		.0143
41.....	400	1	A	120		68		.....
40.....	300	1	A	80	89	64	70	.....
51.....	300	1	A	130		64		.....
42.....	200	1	A	110		66		.0027
23.....	.....	0	A	95	89	75	70	.....
24.....	.....	0	A	100		74		.....
28.....	.....	0	A	80		66		.....
29.....	.....	0	A	80		66		.0383

RESULTS OF REPROCESSING

Tests to determine the effect of reprocessing on an earth's bleaching power were made (Table 4). In these tests the oil retained in the filter cake was driven off at a temperature of 600° C. for a period of one hour; the use of a solvent previous to reprocessing would have been more desirable. According to the results, Anna kaolin may be reprocessed many times without affecting its bleaching power, the rate of filtration, the amount of oil retained by the filter cake, or the peroxide oxygen content of the bleached oil.

TABLE 4—*Results of tests on bleaching 300 grams of cottonseed oil with 16 grams of reprocessed Anna kaolin, digested at 120°C. for five minutes*

(Earth processed at 600°C. for one hour)

Laboratory test number	Times reprocessed	Color of bleached oil	Rate of filtration (number seconds)	Retention of oil (per cent of original earth)	Peroxide oxygen mols per 1000 grams
49.....	1	A	90	61	.0006
50.....	2	A	75	61	.0005
52.....	3	A	100	58	.....
53.....	4	A	140	58	.0099
54.....	5	A	100	63	.0059
60.....	6	A	80	61	.0131
61.....	7	A	80	64	.....
62.....	8	A	60	57	.0132
63.....	9	B	100	54	.....
64.....	10	A	140	66	.0175
65.....	11	A	150	62	.....
84.....	12	A	60	61	.0084
(Mean).....				61	.....

TESTS ON BLEACHING LARD WITH ANNA KAOLIN

Qualitative tests indicate that Anna kaolin bleaches lard to the same degree as an equal amount of English XL fuller's earth.

TESTS ON BLEACHING MOTOR OIL WITH VARIOUS EARTHS

The comparative ability of several earths to bleach motor oil was tested by using acid stock motor oil with viscosity of 150, furnished by the Sinclair Refinery at Coffeyville, Kansas (Table 5). The results show that clay from LaSalle, Pulaski, and Union counties, Illinois, and bentonite clay from Arkansas are inert. All other earths have excellent bleaching properties. The Parm and Mounds deposits are the same type of earth as that being produced commercially near Olmstead. The Anna kaolin appears to be the best earth, giving the best color and retaining the least amount of oil of all the earths tested.

The tests show that samples of earth taken from different positions in the same deposit, although radically different in texture and composition, possess bleaching strength much closer to one another than do earths of like texture and chemical composition from different localities. The fact that the bleaching power of earths from the same deposit do not vary, despite the large amounts of quartz that occur as an impurity in some of them, seemed so strange that bleaching tests were made on both the purified and the waste fractions from samples in which approximately 50 per cent is waste. It was found that the pure concentrate and the impure tailings possessed practically the same bleaching strength. This led to the idea that fine quartz, which is the principal constituent of the tailings, might in itself possess bleaching strength equivalent to the quartz found as an impurity in the bleaching earth, and so samples of extremely fine air-floated and water-floated silica were tested for bleaching power but yielded negative results. The activity of the silica in the Olmstead earth may be due either to a thin layer of active clay on the surface of the inert silica particles, or it may be due to the fact that the surface of the silica is itself activated. The second possible condition would be analogous to the surface activity of silica gel.

TABLE 5—Results of tests on bleaching 500 grams of motor oil with various earths, digested at 82°C. for twenty-five minutes

Earth and source	Chief mineral (a)	Test No.	Earth (ratio to oil, per cent)	Oil retention (per cent of original earth)	Color
Anna kaolin, Mountain Glen, Ill...	Kaolinite-anauxite (b)...	108	15	65	AA
Anna kaolin, Miller pit, Mountain Glen, Ill.....	Kaolinite-anauxite (b) ..	122	15	.....	A
Anna kaolin, Mountain Glen, Ill...	Kaolinite-anauxite (b)...	114	10	.....	A
Fuller's earth (light earth), Parm deposit, Pulaski County, Ill.....	Montmorillonite.....	111	15	145	A
Fuller's earth (dark earth), Parm deposit, Pulaski County, Ill.....	Montmorillonite.....	112	15	148	A
Fuller's earth (light upper earth), Mounds deposit, Pulaski County, Ill.....	Montmorillonite.....	118	15	195	A
Fuller's earth (dark lower earth), Mounds deposit, Pulaski County, Ill.....	Montmorillonite.....	119	15	100	A
German Fuller's earth, Terrana brand.....	Montmorillonite.....	104	15	191	A
Fuller's earth, Attapulugus Fullers Earth Co., Attapulugus, Ga.....	Montmorillonite.....	105	15	141	A
Fuller's earth, Western Clay and Metals Co., Ivie, Utah.....	Montmorillonite.....	115	15	76	A
Fuller's earth, Standard Fullers Earth Co., San Antonio, Tex...	Montmorillonite.....	120	15	95	A
Fuller's earth, Maeon, Ga.....	Montmorillonite.....	124	15	124	A
Fuller's earth, Floridin County, Floridin, Fla.....	Montmorillonite.....	125	15	165	A
Fuller's earth, General Reduction Co., Twiggs County, Ga.....	Montmorillonite.....	123	10	134	A
Bentonite, Saline County, Ark.....	Montmorillonite.....	116	15	95	D
Clay, Herrick Clay Manufacturing Co., Buffalo Rock, Ill.....	(c).....	107	15	138	D
Clay, Grothman pit, north of Metropolis, Massac County, Ill.....	(c).....	121	15	70	D
Clay, Schick clay pit, south of Grand Chain, Pulaski County, Ill.....	(c).....	117	15	120	D

(a) Determined according to optical properties.

(b) The mineral is a member of the isomorphous kaolinite-anauxite series but data are lacking to place its position within the series.

(c) The optical properties of this clay approximate those of a beidellite clay high in the nontronite member. In 1931 Kerr reported to Allen of this Survey that the X-ray patterns of this clay differ from those of the beidellite group. Likewise after the preparation of this manuscript Kerr substantiated the above difference on additional samples submitted by Grim. Work on the mineral classification of this clay is in progress.

TESTS ON BLEACHING ENGINE OIL WITH VARIOUS EARTHS

The comparative ability of several earths to bleach engine oil was tested by using No. 7 N.P.A. red oil furnished by the Sinclair Refinery Company. The results show that the Anna kaolin is a good bleaching agent for engine oil and does not retain excessive amounts of oil. It is the only kaolin tested

that possesses good bleaching power. The kaolins from South Carolina, from Georgia, and from Florida, and the MM English brand show some bleaching power but the others are extremely inert. The aluminum hydroxide has good bleaching strength but it could be processed and used only with difficulty because of its hygroscopic nature.

TABLE 6—Results of tests on bleaching 500 grams of red engine oil with various earths, digested at 82°C. for twenty-five minutes

Earth and source	Chief mineral (a)	Lab. Test No.	Earth (ratio to oil, per cent)	Oil retention (per cent of original earth)	Color
Anna kaolin, Mountain Glen, Ill.	Kaolinite-anauxite.	146	15	52	A
Anna kaolin (pulverized by exploding moist earth in furnace at 600°C.), Mountain Glen, Ill.	Kaolinite-anauxite.	131	15	62	A
Anna kaolin (pulverized by exploding heated earth 500°C. in water), Mountain Glen, Ill.	Kaolinite-anauxite.	132	15	63	A
Anna kaolin (white earth from depth of 40 feet, processed at 600°C.), Mountain Glen, Ill.	Kaolinite-anauxite.	144	15	47	A
Anna kaolin (run-of-mine, processed at 600°C.), Mountain Glen, Ill.	Kaolinite-anauxite.	147	15	68	A
Anna kaolin (chalky earth from depth of 50 feet, processed at 600°C.), Mountain Glen, Ill.	Kaolinite-anauxite.	148	15	70	B
Anna kaolin (red iron oxide earth processed at 600°C.), Mountain Glen, Ill.	Kaolinite-anauxite.	149	15	88	B
Clay, clay pits near Drake, Greene County, Ill.	(b)	137	15	20	D
Clay, W. Guthrie farm, north of Belleview, Calhoun County, Ill.	Kaolinite-anauxite and (b)	140	15	46	D
Kaolin, South Carolina (supplied by Ceramics Dept., University of Illinois)	Kaolinite-anauxite halloysite.	128	15	62	C
Kaolin, Georgia (supplied by Ceramics Dept., University of Illinois)	Kaolinite-anauxite.	129	15	69	C
Kaolin, Florida (supplied by Ceramics Dept., University of Illinois)	Kaolinite-anauxite.	130	15	78	C
Kaolin, Spruce Pine, North Carolina (supplied by Ceramics Dept., University of Illinois)	Kaolinite-anauxite.	133	15	75	D
English kaolin (china clay), H. & G. brand, supplied by Ceramics Dept., University of Illinois.	Kaolinite-anauxite.	134	15	85	D
English kaolin (china clay), M. & M. brand, supplied by Ceramics Dept., University of Illinois.	Kaolinite-anauxite.	135	15	75	D

TABLE 6—Concluded

Earth and source	Chief mineral (a)	Lab. test No.	Earth (ratio to oil, per cent)	Oil retention (per cent of original earth)	Color
Flint clay, locality four miles west of St. Clair, Missouri.....	Kaolinite, halloysite....	138	15	32	D
Clay, Gardner pit, Lawrence County, Indiana.....	Halloysite, kaolinite....	141	15	44	C
Mahogany clay, Gardner pit, Lawrence County, Indiana.....	Halloysite, kaolinite, with much brown limonite..	142	15	40	D
English Fuller's earth, XL brand...	Montmorillonite.....	150	15	59	A
German Fuller's earth, Terrana brand.....	Montmorillonite.....	145	15	38	A
Fuller's earth, Watson pit, Pulaski County, Ill.....	Montmorillonite.....	126	15	79	A
Clay, John V. Wyatt clay pits, Whitehall, Greene County, Ill...	(b).....	139	15	30	D
Fuller's earth, Delight, Arkansas...	Montmorillonite.....	136	15	.....	A
Aluminum hydroxide veinlets in coal, Pinckneyville, Ill.....	.....	143	15	118	B

(a) Determined according to optical properties.

(b) The optical properties of this clay approximate those of a beidellite clay high in the nontronite member. In 1931 Kerr reported that the X-ray patterns of this clay differ from those of the beidellite group. Likewise after the preparation of this manuscript Kerr substantiated the above differences on additional samples submitted by Grim. Work on the mineral classification of this clay is in progress.

TESTS ON VARYING THE TEXTURE OF ANNA KAOLIN

Tests were made to determine whether or not the texture of the Anna kaolin affected its bleaching power (Table 7). The results show that neither expansion nor compaction of the earth affect its bleaching power.

The specific gravities shown in the table are only relative as they were obtained by the following procedure: A 60-cc. Erlenmeyer flask was weighed; the flask filled level full, while being gently shaken, with earth which had been pulverized to pass a 200-mesh screen and dried thoroughly; the earth and flask weighed; the weight of the earth determined by subtracting the weight of the flask from the total weight; and the weight of the earth in grams divided by 60.

As shown in the table, the specific gravity of the compacted earth is approximately the same as that of the regular earth, whereas the exploded earth is heavier. An untreated sample of kaolin taken from an unused pit and different from the regular kaolin in that it is much more weathered, lighter in weight, has a greasy surface, and is difficult to grind and sift, has a much lower specific gravity than the regular kaolin.

TABLE 7—Results of tests to determine effect of variation of texture on bleaching efficiency of Anna kaolin

Preliminary treatment of Anna kaolin	Oil	Earth (ratio to oil, per cent)	Color of bleached oil	Rate of filtration (number of seconds)	Oil retention (per cent of original earth)	Specific gravity	Weight in lbs. per cu. ft.
Exploded by dropping moist earth in furnace at temperature of 600°C.	Red engine..	15	A	.....	62.4	.62	38.8
Exploded by dropping heated earth (500°C.) into water.	Red engine..	15	A—	.....	63	.....	.....
Exploded in bomb at 350°C. and under pressure of 2,400 lbs. per sq. in.	Cottonseed..	6	AA	120	44	.....	.....
Compacted under pressure of 80,000 lbs. per sq. in.	Cottonseed..	5.3	A	.....	63	.52	33.5
Regular untreated.	Cottonseed..	6.0	.....	240	120	.53	33.2
Special untreated.	.....	.....	.....	.....	.....	.42	26.3

CHEMICAL ANALYSES

Chemical analyses of unpurified Anna kaolin and of kaolins from outside the State, made previous to this study, are given in tables 8 and 9. A current analysis of a sample of Anna kaolin purified by sedimentation, is as follows:

	Per cent
SiO ₂	48.18
Al ₂ O ₃	30.72
Fe ₂ O ₃	1.59
FeO	.40
MgO	.84
CaO	1.02
Na ₂ O	.01
K ₂ O	.29
H ₂ O—	.73
H ₂ O+	14.11
TiO ₂	1.20
P ₂ O ₅	.90
Total	99.99

TABLE 8—Chemical analyses of Anna kaolin from Goodman Deposit, see, 35, T. 11 S., R. 2 W., Union County, Illinois (a)

Sample	Depth in feet	H ₂ O	SiO ₂	F ₂ O ₃	Al ₂ O ₃	TiO ₂	Ratio $\frac{\text{SiO}_2}{\text{R}_2\text{O}_3}$
D14.....	Top to 20 (white).....	11.48	52.65	0.97	33.98	2.92	2.66
D13.....	Top to 20 (slightly yellowish)	9.95	47.95	1.23	37.86	3.01	2.18
D12.....	35 to 40.....	9.50	56.55	1.23	29.97	2.75	3.13
D11.....	40 to 44.....	16.34	48.30	1.02	31.14	3.20	2.67
D10.....	50 to 84.....	11.15	43.90	1.76	40.79	2.40	1.85

(a) Purdy, R. C., and De Wolf, F. W., Preliminary Investigation of Illinois fireclays: Illinois State Geol. Survey Bull. 4, p. 175, 1907.

TABLE 9—*Chemical analyses of kaolins from localities outside of Illinois (a)*

Source	SiO ₂	Al ₂ O ₃	Ratio $\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$
1. Anglesey, Colorado (p. 59).....	46.53	38.93	2.06
2. Red Mountain, Colorado (p. 59).....	46.35	39.59	2.01
3. Webster, North Carolina (p. 320).....	46.70	40.61	1.94
4. Webster, North Carolina (p. 320).....	62.40	26.51	4.70
5. Webster, North Carolina (p. 320).....	45.78	36.48	2.15
6. Brandywine Summit, Pennsylvania (p. 320).....	46.28	36.25	2.20
7. Upper Mill, Pennsylvania (p. 320).....	73.80	17.30	7.34
8. West Cornwall, Connecticut (p. 320).....	46.50	37.40	2.14
9. Glen Allen, Missouri (p. 320).....	72.30	18.94	6.57
10. Leaky, Edwards County, Texas (p. 321).....	45.44	40.30	1.90
11. Cord Spring, Virginia (p. 321).....	43.31	39.42	1.89
12. Cornwall, England (p. 321).....	48.26	37.64	2.21
13. Zettlitz, Bohemia (p. 321).....	46.87	38.00	2.11
14. Coussac-Bonneval, France (p. 321).....	47.71	36.78	2.25

(a) Ries, H., *Clays, occurrence, properties and uses*. John Wiley and Sons.

Data for the dehydration curves were obtained by heating one-gram samples for one hour at each of the various temperatures (Fig. 7).³ It should be noted that the Anna kaolin has a critical temperature of dehydration whereas the fuller's earth from Olmstead has a gradual dehydration. Inasmuch as fuller's earth is processed at about 300°C., the curve shows that processing drives off one per cent of moisture in addition to that lost by normal sun-drying. In contrast, Anna kaolin is processed at 600°C., and consequently loses 11 per cent of moisture over that lost by sun-drying. Tests (Tables 2 and 3) indicate that the temperature of processing and consequent large loss of water of dehydration does not affect the bleaching power of the kaolin but does reduce the peroxide oxygen content and thereby the potential rancidity of the oil. The radical difference between the dehydration curves of fuller's earth and Anna kaolin suggest that they would have different bleaching properties, and this difference as well as the refractoriness of the Anna kaolin may account for the fact that Anna kaolin may be reprocessed repeatedly without affecting its bleaching power whereas fuller's earth is not subject to reprocessing.

The Anna kaolin exhibits a wide range of structure and composition with comparatively constant bleaching strength. Analyses of kaolins outside of Illinois (Table 9) show a close agreement to a definite silica-alumina ratio of 2, except for three—Nos. 4, 7, and 9—which doubtless contain sufficient admixed quartz to produce the higher ratio; this suggests that the Anna kaolin is in a transitional stage of weathering as compared to other kaolins which are in a stabilized stage.

³ This method was used by Ross and Kerr, as described in: *The Kaolin Minerals*, U. S. Geol. Survey, Prof. Paper No. 165-E, 1931.

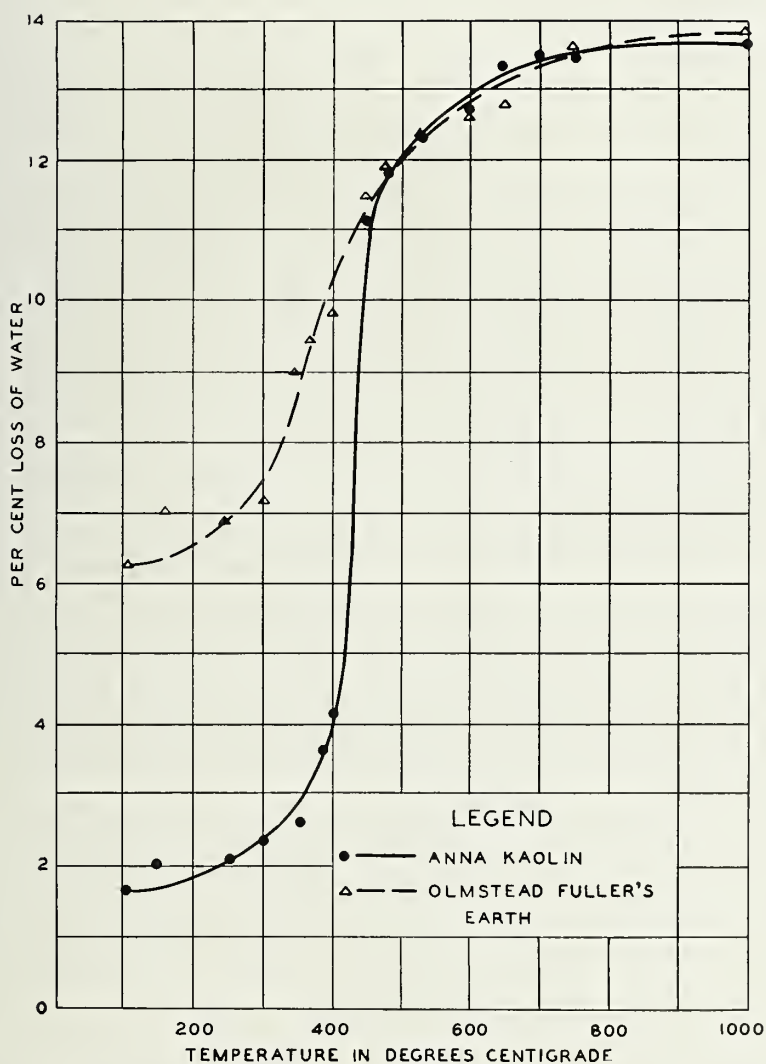


Fig. 7.—Dehydration curves for Anna kaolin and Olmstead fuller's earth.

MINERAL ANALYSIS

On the basis of their optical properties, the dominant minerals in the Anna kaolin have been determined to belong to the kaolinite-anauxite isomorphous series⁴ and this determination has been recently verified by chemical analysis, X-ray analysis, and dehydration tests. The theoretical formulae of kaolinite and anauxite are $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$, and $\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 2 \pm \text{H}_2\text{O}$ respectively.⁵

The $\text{SiO}_2:\text{R}_2\text{O}_3$ ratio in the purified Anna kaolin (p. . .) is 2.57 whereas in the unpurified kaolin it varies from 1.85 to 3.13 (Table 8). These results are not strictly comparative because in the unpurified material, part of the SiO_2 is in the form of free silica rather than aluminum silicate and it is possible that some of the Al_2O_3 may be in the form of hydrated aluminum oxide rather than aluminum silicate, but they show the wide variation in the composition of the kaolin.

The Anna kaolin contains quartz grains which are very rare except in small lenticular zones where they make up as much as 80 per cent of the total earth. In some of these zones the clay mineral associated with the quartz grains is halloysite, which occurs in grains so small that the aggregate appears non-crystalline.

Very small grains of pyrite, calcite, zircon, kyanite, tourmaline, rutile, staurolite, epidote, anatase, and muscovite occur rarely in the Anna kaolin. Yellowish-red limonite occurs as small fragments and occasionally stains the clay.

Beidellite has the composition $\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot n\text{H}_2\text{O}$, and is usually associated isomorphously with the various amounts of nontronite ($\text{Fe}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot n\text{H}_2\text{O}$). Montmorillonite, which occurs as the principal mineral constituent in all the tested fuller's earths, has the composition $\text{Al}_2\text{O}_3(\text{MgO} \cdot \text{CaO}) \cdot 5\text{SiO}_2 \cdot n\text{H}_2\text{O}$ and is another member of the isomorphous series.⁶

DEVELOPMENT OF ANNA KAOLIN FOR BLEACHING

As edible oils require a bleaching earth of higher quality than that suited to mineral oils, the Anna kaolin should be considered primarily as a new local source of bleaching earth for edible oils rather than as a competitor to the local fuller's earth industries already developed.

If the Anna kaolin is to compete successfully with standard brands of bleaching earths for edible oils, it is important that the producer be able to guarantee a uniform product. This may be done most efficiently by washing out the intermingled sand which in the Anna deposit ranges from less than one per cent in certain portions to all sand in certain zoned portions.

⁴ Ross, C. S., and Kerr, P. F., The kaolin minerals, U. S. Geol. Survey Prof. Paper No. 165-E, pp. 151-176, 1931.

Allen, V. T., Unpublished notes in the files of the Illinois State Geol. Survey.

⁵ Ross, C. S., and Kerr, P. F., Op. cit.

⁶ Ross, C. S., and Kerr, P. F., The clay minerals and their identity: Jour. Sedimentary Petrology, vol. 1, pp. 58-64, 1931.

The proposed water classification invites serious consideration of hydraulic mining. The steam shovel method has proved satisfactory only for high rates of production. Shaft or tunnel mining is expensive due to the necessary cribbing and is wasteful due to the fact that more than 50 per cent of the clay is left in the retaining walls. It is estimated that hydraulic mining, as compared to shaft or tunnel mining, would result in greater ultimate recovery and in lower cost of production that would more than offset the added cost of washing.

A continuous rotary kiln is desirable for processing for one hour at 600°C. the Anna kaolin which is to be used for bleaching. Standard equipment, such as that used in any fuller's earth plant, may be used for pulverizing the processed Anna kaolin to desired sizing.

Pilot plant tests indicate that, in order to develop its full bleaching strength, the earth must be sized to approximately 98 per cent less than 200-mesh, or similarly to sizing of earths in common use for bleaching cottonseed oils. The dust must be removed from the earth in order to prevent the filter presses from being clogged.

The processing plant for Anna kaolin may be located (a) at the deposits, (b) at a central distribution point, or (c) at a location en route; the last would permit possible advantages in freight rates. The use of hydraulic mining and washing will not influence the site of the processing unit.

INTERPRETATION OF THE BLEACHING PROPERTY OF ANNA KAOLIN

The following hypothesis has been developed in an effort to explain the bleaching property of Anna kaolin: During the weathering of clays it appears that silica is leached out in preference to alumina, so that with increasing geologic age the ratio of silica to alumina is lowered. In fuller's earth the ratio is 5, in kaolin it is 2 (Table 9), and in bauxite the silica has been entirely leached out. In Anna kaolin the ratio ranges from 1.85 to 3.13 (Table 8), indicating that this deposit is in a transitional stage. Inasmuch as the true kaolins are low in bleaching strength, it is suggested that the bleaching property of the Anna kaolin is related to its transitional state in the weathering process. If this is true, a clay, during weathering, may pass through certain stages when it possesses strong bleaching properties, and alternate stages when it is inert. The bleaching activity at certain stages is apparently an experimental verification of unusual surface energy of particles of bleaching earth at transitions between stable points in its metamorphosis.

The apparent correlation between the bleaching property and the transitional stage of weathering of Anna kaolin suggested that a like correlation might be found true for a radically different earth. Accordingly, bleaching tests were made on an aluminum hydroxide clay, also in an apparent transitional stage of weathering, and the results substantiated such a relationship.

This suggests the possibility that other types of earth which are passing through transitional stages of weathering may be found to possess bleaching properties.

ACKNOWLEDGMENTS

Mr. J. C. Boyd, manager of the Illinois Kaolin Company, supplied samples of Anna kaolin for pilot plant tests and also furnished information as to the previous production of Anna kaolin. Mr. H. P. Miller, mine manager of the French Clay Blending Company, supplied samples of clay typical of various kinds of Anna kaolin.

Dr. R. C. Newton, Director of Research, Swift and Company, furnished information regarding standardized laboratory procedure in bleaching cottonseed oil and animal lard and supplied the unbleached cottonseed oil and lard used in the tests and also samples of English XL fuller's earth which they consider a standard for comparison with other bleaching earths. Also Dr. Newton made pilot plant tests on Anna kaolin.

Mr. Lloyd Cannon, manager of the fuller's earth plant of the Sinclair Oil Company, Olmstead, Illinois, and Mr. J. F. Shanley, Superintendent of the plant of the Standard Oil Company of Indiana, Olmstead, Illinois, furnished information as to their methods of mining and processing fuller's earth. Mr. Cannon also provided samples both of Olmstead fuller's earth and other earths from without the State. Mr. E. P. Phillips, chief chemist of the Sinclair Oil Company at the East Chicago refinery, provided data concerning the standardized quantitative tests for bleaching mineral oil and supplied the unbleached motor and red engine oil which were used in some of the tests.

Representative samples of clay were collected from various localities in the State by Mr. J. E. Lamar, Geologist and Head of the Non-Fuels Division, Dr. R. E. Grim, Petrographer, and Dr. V. T. Allen, Petrographer, Illinois State Geological Survey. Dr. G. H. Cady, Senior Geologist and Head of the Coal Division of the Survey, furnished the sample of aluminum hydroxide clay. Dr. H. R. Wanless, Assistant Professor of Geology, of the University of Illinois, collected the flint clay from near St. Louis, Missouri. Professor C. W. Parmelee, Head of the Department of Ceramic Engineering, University of Illinois, provided the six samples of kaolin from localities outside Illinois. Mr. A. M. Davis, President of International Silica Company, supplied samples of air-floated and water-floated silica. Typical earths from outside the State were also furnished by Dr. W. N. Logan, State Geologist of Indiana; Dr. S. W. McCallie, State Geologist of Georgia; Dr. J. C. Branner, State Geologist of Arkansas; and Dr. Herman Gunter, State Geologist of Florida.

The bleaching tests were made by Mr. H. C. Roberts, Physics Assistant. The summary of the geology of the Anna kaolin deposits was written by Mr.

Lamar. The minerals in the clays were identified by Dr. Grim. Chemical analyses of the clays, the determination of the dehydration curve of Anna kaolin and of the peroxide oxygen content of the bleached oils were made under the supervision of Dr. O. W. Rees, Associate Chemist, Analytical Division. Dr. W. H. Voskuil, Mineral Economist, prepared the economic analysis. Appreciation is expressed for the continued interest and enthusiasm of Dr. M. M. Leighton, Chief of the Survey, who made this work possible.

CHAPTER III—GEOLOGY OF THE ANNA KAOLIN DEPOSITS

By J. E. Lamar

Introduction and acknowledgments.—The existence of kaolin in the vicinity of Kaolin Station, about one mile southwest of the village of Mountain Glen, Union County, Illinois, has been known for years.¹ Production was greatest during the World War at which time the deposit was best exposed. Since then production has been comparatively small and most of the former workings have been abandoned so that now they have slumped and washed to such an extent that little detail concerning the deposits can be seen. The present discussion is therefore largely a summary of previously published information supplemented by field data collected by Mr. Frank Krey and Dr. George E. Ekblaw during their study of the geology of the Alto Pass quadrangle and by observations made by the writer.

Occurrence and topographic position.—The clay at Mountain Glen occurs chiefly as limited bodies in local depressions which are either ancient sink holes or valleys in bedrock, and is therefore not a continuous sheet or blanket deposit.

The topographic position of the deposits is quite variable. Most of the deposits which have been commercially exploited on a large scale were located in the lower slopes of the west valley-wall or in the flat of a small tributary to Clear Creek. More or less outlying operations were situated in deposits well up on the hillsides, and regrading these, St. Clair² states, "Some of the conditions of occurrence are similar to those found at the main deposits, but the clay is apparently of different quality [as affecting its ceramic uses]. It is not very plastic, and resembles more a pottery clay. The color is pink and white and the texture is fine grained."

Character.—The known deposits of the main producing area consist principally of clay relatively free from interbedded, non-clay materials but locally contain thin layers or irregular bodies of sand, possibly water-bearing, or sandy clay, mostly of minor importance from the standpoint of the production of a uniform product, especially if the clay is washed. Lenses of lignite or lignitic clay are locally present but are not extensive or thick, except possibly in the bottoms of the deposits.

¹ Worthen, A. H., *Geology of Illinois*, vol. III, p. 52, 1868.

Purdy, R. C., and DeWolf, F. W., *Illinois fire clays*: Illinois State Geol. Survey Bull. 4, pp. 173-175, 1907.

St. Clair, Stuart, *Clay deposits near Mountain Glen, Union County, Illinois*: Illinois State Geol. Survey Bull. 36, pp. 71-83, 1920.

Parmelee, C. W., and Schroyer, C. R., *Further Investigations of Illinois fire clay*: Illinois State Geol. Survey Bull. 38-D, pp. 42-64, 1921.

² St. Clair, Stuart, *Idem* p. 78.

All reported deposits appear to conform roughly to the following general sequence of clay and associated beds, somewhat modified from St. Clair³ although all beds are not always or necessarily present in all deposits.

General sequence of beds in kaolin deposits

- | | |
|--|--|
| 8. Loess | |
| 7. Gravel | |
| 6. Red and white sand with some clay pockets | |
| 5. Pink clay and/or mottled pink and white clay | } Locally represented by
brown clay |
| 4. White clay | |
| 3. Bluish white clay with lignitic material in basal portion | |
| 2. Sand | |
| 1. Limestone | |

Most of the clay is plastic, much of it highly so. In general it is free from impurities, such as pyrite, mica, and sand, but locally contains a variety of mineral grains which, however, constitute but a small percentage. At many places where the clay adjoins sand or lignite, it is pyritic and sandy.

The kaolin is chiefly bluish-white, white, pink, and mottled pink and white, locally chocolate-colored where associated with lignite. The general relation of these different varieties of clay to each other is shown in the generalized section above.

Thickness.—The thickness of the deposits varies greatly from pit to pit or even from place to place in any one pit. The maximum thickness reported in borings is 93 feet and thicknesses of about 70 feet are relatively common. The lower bluish-white clay ranges from 15 to 40 feet thick in known deposits and appears to average about 25 to 35 feet. Locally, the basal part of this clay may be interbedded with lignite for a thickness known to be as much as 17 feet. The white clay overlying the bluish-white clay has a maximum thickness of 10 feet in one deposit where it is reported as a distinct layer. The overlying pink and/or pink and white mottled clay has a maximum thickness of 57 feet as reported in the Goodman shaft and is 15 feet thick in the pits of the Illinois Kaolin Company. Locally, the position of this clay and the subadjacent white clay appears to be occupied by brown clay of which a maximum of 14 feet is shown in records of the French Clay Blending Company.

Extent.—The only known commercial deposits of kaolin in southern Illinois occur in the vicinity of Mountain Glen, although it is possible that similar deposits may occur elsewhere in that portion of the State. The extent of the area likely to contain kaolin in the Mountain Glen region is shown in figure 2, p. 8.

The extent of individual deposits is probably highly variable. In 1918, Illinois Kaolin Company's pit K3, the largest in the area, measured 200 by 300 feet and was 80 feet deep at the west end but shallower at the east end. The horizontal dimensions of this pit are probably roughly typical of the larger deposits in the area.

Character of floor.—Although little specific information regarding the floor of the kaolin deposits is available, it is reported that in some deposits

³ St. Clair, Stuart, Idem, p. 79.

the clay rests on sand which in turn probably lies on limestone bedrock; locally the clay rests directly on the limestone. The surface of the limestone is probably uneven. Generally the bottom of the clay deposit is more even where it rests on sand than where it rests directly on the limestone, although locally its contact with the sand may be also irregular.

Overburden.—The overburden generally consists of (1) sand as much as 20 feet thick, overlain by (2) a few inches to 8 feet of gravel, thickest in the stream-flats, in turn capped by (3) brown clayey silt (loess) as much as 15 feet thick. The gravel may be locally cemented to form conglomerate. According to reports the overburden on known deposits ranged from 8 to 40 feet; it averaged about 15 feet at the large pit of the Illinois Kaolin Company.

Recovery methods.—Three methods have been used in exploiting the kaolin deposits: (1) open-pit mining with steam shovels, (2) crib or shaft diggings, and (3) shaft-and-tunnel mining. The first method recovers the largest percentage of the available clay. The cribs of the second method are not known to have been uniformly spaced by the various operators. However, the practice at one of the mines consisted of digging shafts 14 by 14 feet in cross-section separated by walls about 7 feet thick, thus recovering about 45 per cent of the available clay. No data on the percentage of clay recovered by the tunnel method are available but it is probably least efficient.

Recommendations for prospecting.—If additional deposits exist, they most probably occur in the lower portions of or near the mouths of small valleys, although some deposits may be found at higher positions. From present information the tops of ridges are not thought to be highly promising areas for the occurrence of kaolin in large deposits.

Individual deposits should be thoroughly tested in order to ascertain their lateral and vertical extent. Prospecting in partly worked-out areas must take account of the methods of mining formerly used so that the amount of recoverable clay may be accurately determined.

CHAPTER IV—MARKETING OF ANNA KAOLIN

By W. H. Voskuil

PRODUCTION

The use of fuller's earths in bleaching mineral, vegetable, and animal oil has constantly expanded except during the post-war depression of 1921 and the current depression. In the latter period, the industry did not decline until 1931.

Fuller's earths are used principally in the petroleum industry and to a minor extent in refining vegetable and animal oils. Consumption has been as follows:

Tons of earth used for bleaching

Year	Mineral oils	Vegetable oils and animal fats
1927.....	243,009	15,363
1928.....	258,645	24,288
1929.....	301,607	10,685
1930.....	326,087	8,350
1931.....	(a) 288,000	(b)

(a) Preliminary estimate.
(b) Data not available.

At present prices this represents a value of about three million dollars.

MARKETING

The factors that must be considered in determining the market possibilities of Anna kaolin for bleaching vegetable, mineral and animal oils are (1) cost of mining, (2) size of market area, (3) methods of transportation to consuming centers, and (4) location and quality of competing filtering earths.

Cost of mining.—The cost of mining Anna kaolin ranges from 75 cents to \$1.50 per ton depending upon the conditions at any given pit. This cost, however, represents a small fraction of the cost to the consumer and need not be considered in comparing with competitive earths.

Market area.—The local market area, which includes Illinois, Indiana, Iowa, Michigan, Missouri, Ohio and Wisconsin, contains 47 vegetable oil-refining plants of which 17 are located in Illinois, 15 in Ohio, 5 in Missouri, and

the remaining 10 in the other states; and 73 soap-manufacture plants of which 27 are located in Illinois, 20 in Ohio, 11 in Wisconsin, and 15 in the remaining states. Further, 16 of the oil-refining plants and 24 of the soap factories in Illinois are located in Chicago; 7 of the 15 oil-refining plants in Ohio are in Cleveland, and 12 of the 20 soap factories in Ohio are located in Cincinnati; 8 of the 11 soap manufacturing plants in Wisconsin are in Milwaukee and 1 is in Racine.

The large meat-packing centers are the natural markets for earths used in bleaching animal oils and fats. Although 388 plants are distributed in the Mississippi Valley agricultural belt, 179 are concentrated in Chicago, St. Louis, East St. Louis, Cleveland, Detroit, Indianapolis, Cincinnati, and Milwaukee in order of importance.

Transportation.—Freight costs are naturally dependent upon the methods of transportation available.

The principal markets to be reached by all-rail transportation are Chicago and East St. Louis. The Mobile and Ohio railroad which passes through Kaolin Station provides direct transportation to East St. Louis where connections may be made for shipment to other centers. The Illinois Central railroad passes through the towns of Anna and Cobden about 5 miles east of Kaolin Station and kaolin trucked to these towns can be shipped directly to Chicago.

Both the Mobile and Ohio and Illinois Central railroads run to Cairo where connections with inland waterways are available. There is a nine-foot channel on Ohio River to Cincinnati and points east, a deep waterway on Mississippi River to points south and north, a six-foot channel to Kansas City on Missouri River, and a nine-foot channel on Illinois River to Chicago and lake ports.

SOURCES OF COMPETITIVE EARTHS

Fuller's earth for bleaching animal fats and cottonseed oil is now imported from England and California at costs of \$26.00 and \$54.00 a ton respectively.

The costs of mining, processing, and transportation of the Anna kaolin will permit the material to be delivered to the consuming center at a profit to the producer in competition with imported earths.

APPENDIX

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